



The Role of Sensors in Bridge Health Assessment

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Overview

- ◆ A review of the sensors we have used
- ◆ How have they helped address the basic problems of bridge health assessment
- ◆ It is easy to generate huge data streams. The trick is to make the data actionable.



Basic Concepts

- ◆ Clearly identify the uncertainty you wish to resolve
- ◆ Chose a quantity to measure that most directly reflects the quantity you need to know.
 - Requires a deep fundamental insight into the issue at hand.
- ◆ Present actionable results to the decision maker



Cases we will consider

- ◆ Strain and deflection
 - Superload, Fiber Reinforced Polymer Honeycomb (FRPH) Bridge, Veterans' Glass City Skyway
- ◆ Magnetic sensor for prestressing strand corrosion
 - laboratory and Fayette County Bridge
- ◆ Acoustic monitoring
 - Anthony Wayne Suspension Bridge, Cracks in prestressed concrete adjacent box beam
- ◆ Ground Penetrating Radar
 - Edison Bridge (Route 2 over Sandusky Bay)
- ◆ Ultrasound
 - Cracks in truss pins

Strain and Deflection

◆ Superload

- Uncertainty: Does the large load cause damage?
- Desire to ascertain: changes in stiffness
- Quantity to measure: strain



Strain and Deflection

◆ Superload

- Dump truck test to calibrate FEM and get original bridge response
- Hardened strain gages
 - ◆ Easy to install
 - ◆ Tough to damage

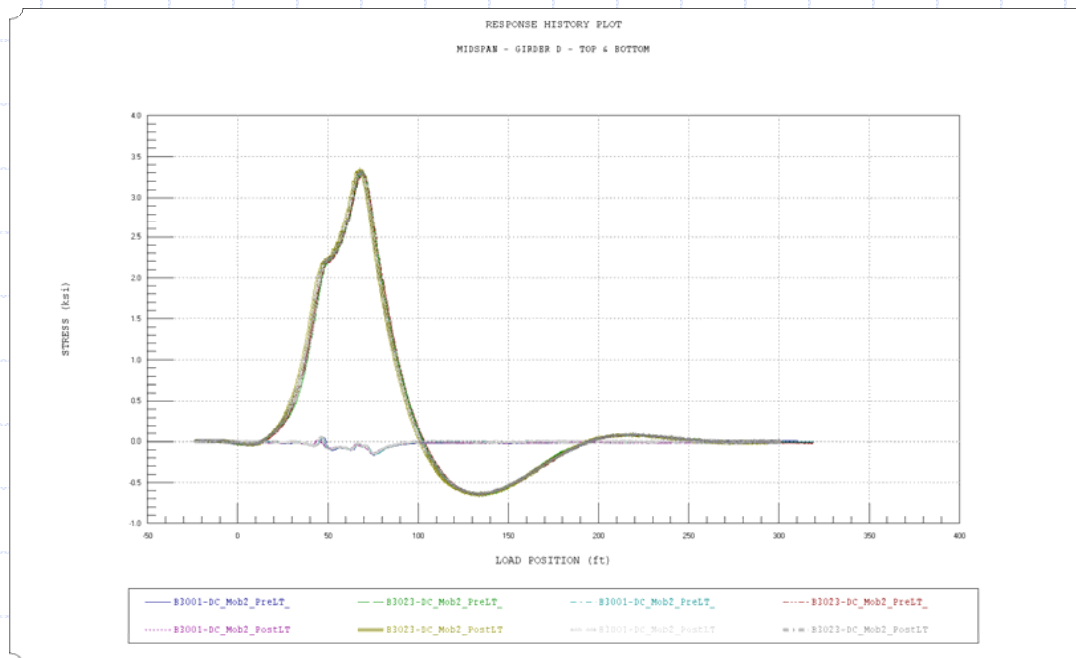




Strain and Deflection

◆ Superload

- Measure response during passage
- Compare before and after passage dump truck strains
- Inspect for cracks



Pre/Post- Double Dump Truck Tests at Girder D Section 2-2 (midspan)



Strain and Deflection

◆ Superload

- Challenge: Extract the superload bridge degradation curve from the data. Maybe the answer is there is no degradation because of the load distribution.

◆ Partners: Profs. Art Helmicki and Victor Hunt and Bridge Diagnostics Incorporated

Strain and Deflection

◆ FRPH Bridge

- Uncertainties: Is the bridge performing as expected? Immediately at opening? After one year?
- Desire to ascertain: changes in stiffness
- Quantities to measure: strain and deflection

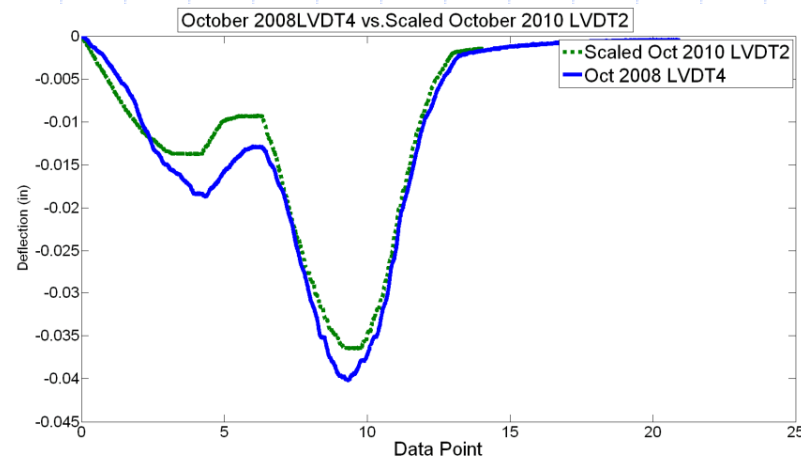




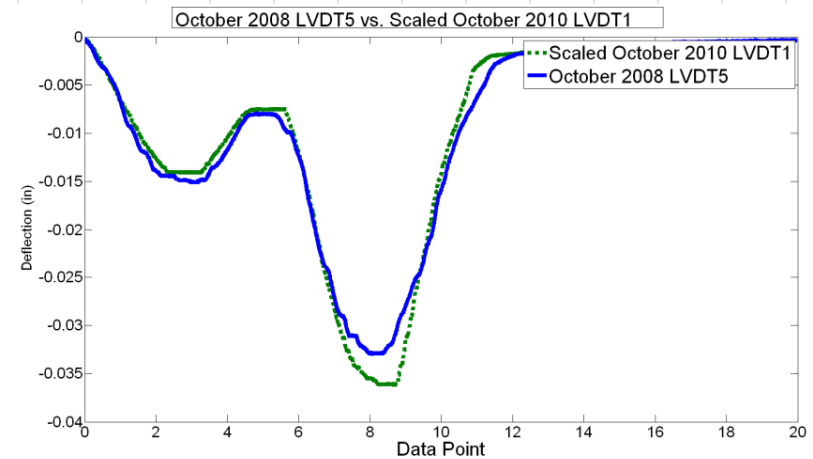
Strain and Deflection

◆ FRPH Bridge

- Measure response during truck load tests upon opening and after one year
- Inspect



LVDT 4 Scaled Data Comparison



LVDT 5 Scaled Data Comparison



Strain and Deflection

◆ FRPH

- Challenge: Establish long term bridge aging characteristics for a new material.

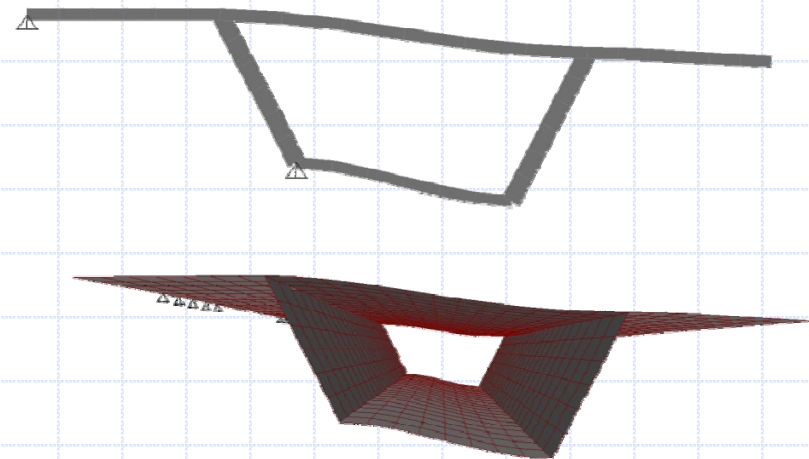
◆ Partners: Huron County Engineer and John Snyder



Strain and Deflection

◆ VGCS

- Uncertainties:
 - ◆ Macro: Is the bridge performing as expected? Immediately at opening? After one year? After 10 years?
 - ◆ Micro: Local strain. concentration
- Desire to ascertain: changes in stiffness local strain
- Quantities to measure: strain at high and low sample speeds
- Embedded strain gages to continuously monitor

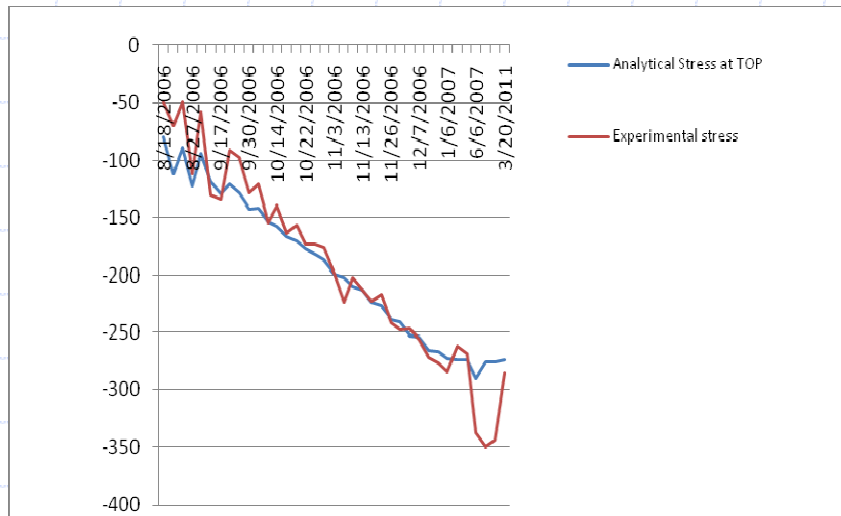




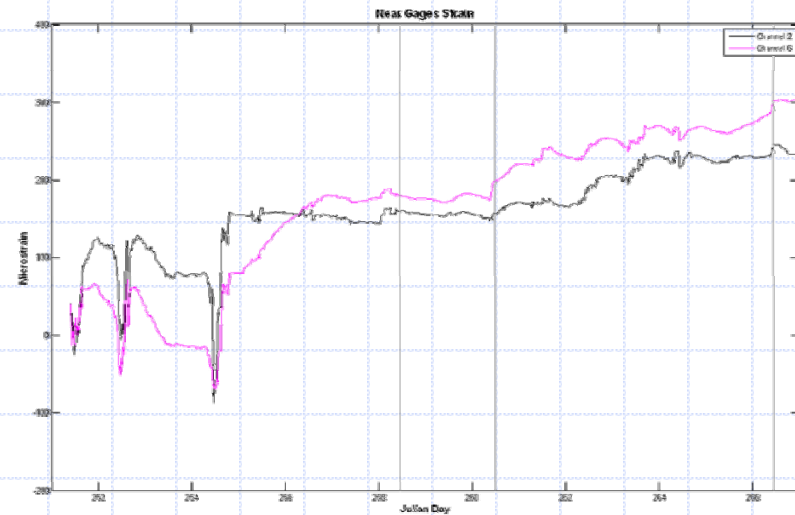
Strain and Deflection

◆ VGCS

- Long term response to deadload
- Short term response to static truck load



Analytical vs Experimental Long Term Response



Local strain is less than cracking threshold



Strain and Deflection

◆ VGCS

■ Challenges

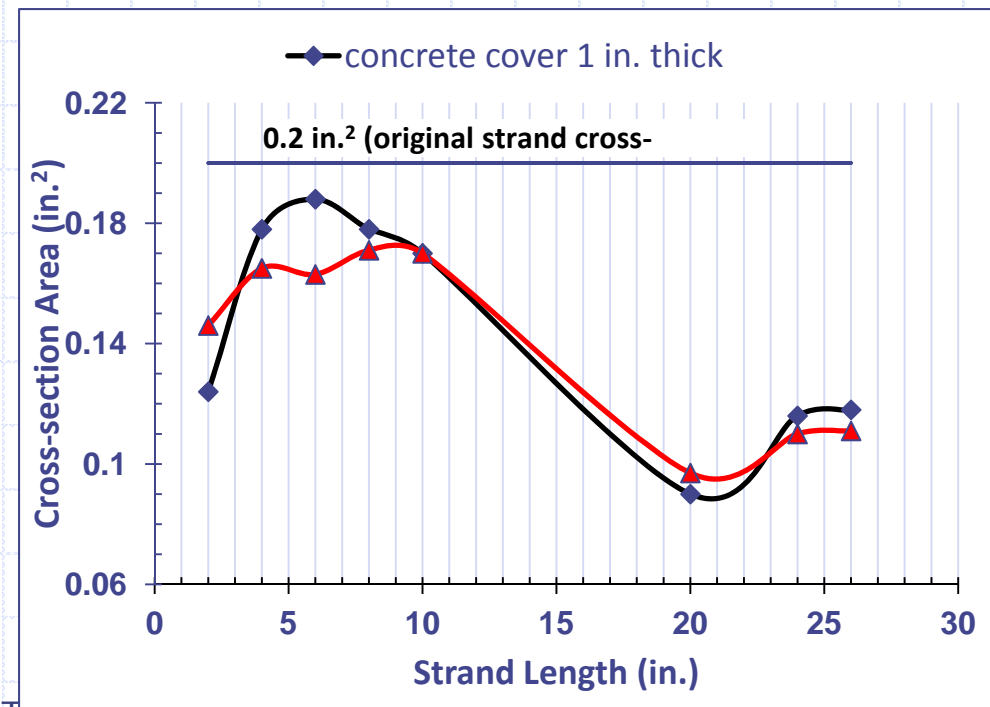
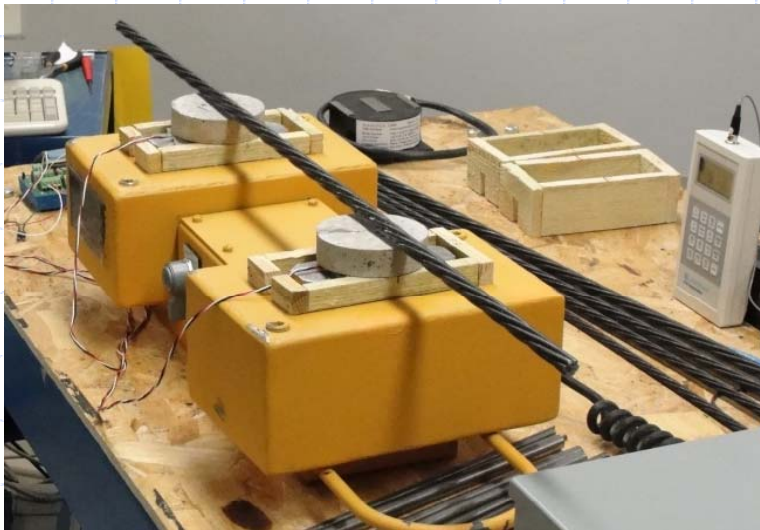
- ◆ Can we make the small changes seen in the long term data useful for understanding the aging of the bridge?

◆ Partners: ODOT, Drs. Helmicki and Hunt

Magnetic Sensor for Invisible Strand Corrosion



- ◆ Uncertainties:
 - Is invisible strand corrosion threatening the safety of older adjacent box beams?
- ◆ Desire to ascertain: area of intact strand nondestructively
- ◆ Quantities to measure: magnetic flux, magnetic leakage or magnetic remanence.

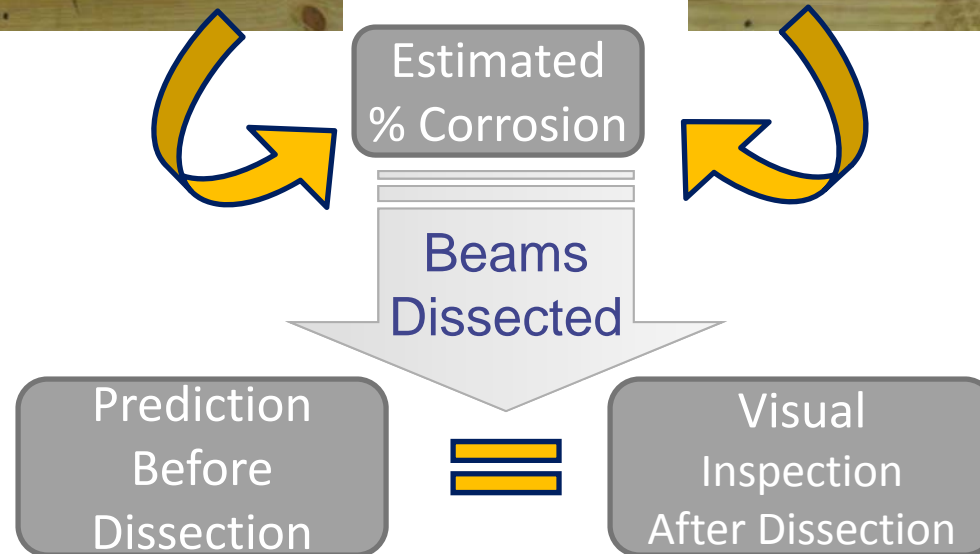


Magnetic Sensor Field Tests

IMF
Method

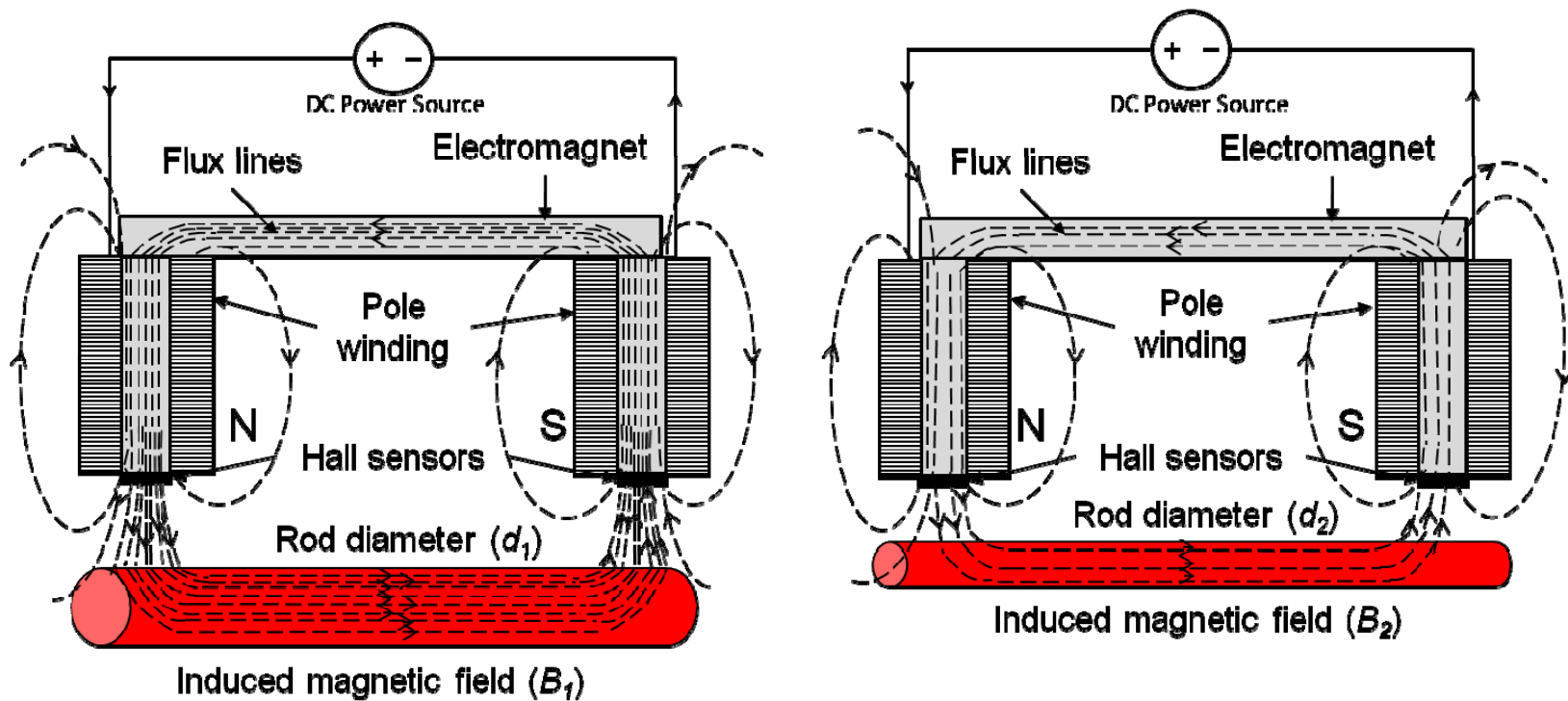


MFL
Method



Magnetic Sensor for Invisible Strand Corrosion

- ◆ Induced magnetic fields depends on specimen diameter



$$d_1 > d_2, B_1 > B_2$$

Magnetic Sensor for Invisible Strand Corrosion



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◆ Challenges

■ Make it practical

- ◆ Physically scanning a smooth soffit is difficult
- ◆ Analytical software
- ◆ Make it so it can be used by a field technician who is not an expert.

◆ Partner: Prof. Al Ghorbanpoor

OTEC 2011

Acoustic Monitoring of the Main Cables of the Anthony Wayne Suspension Bridge



◆ Uncertainties:

- Are the 80+ year old main cables in good enough shape that a rehab of the bridge makes sense?

◆ Desire to ascertain:

- Condition of entire volume of cable nondestructively
- Locations to open for inspection

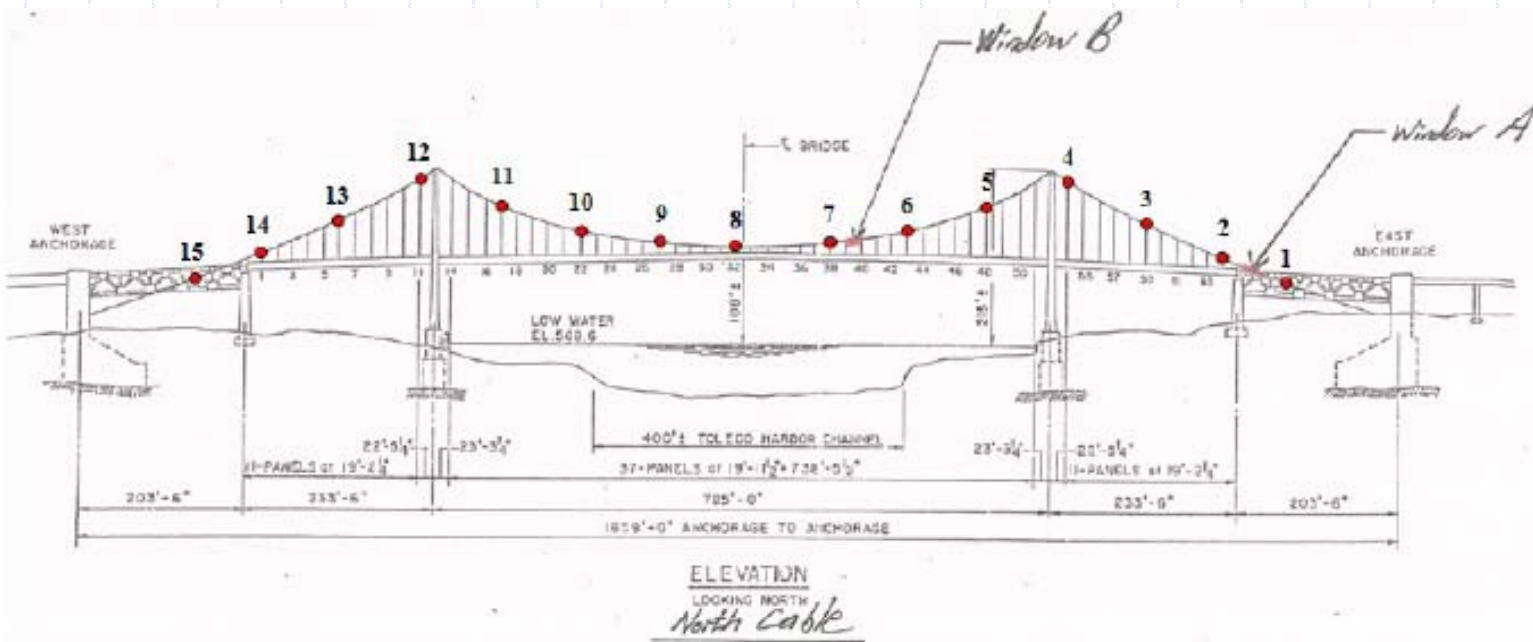
◆ Quantities to measure: acoustic emissions from strand breaks



Acoustic Monitoring of the Main Cables of the Anthony Wayne Suspension Bridge



- ◆ Sensor array
- ◆ Listen for breaks
- ◆ Hear corrosion?





Acoustic Monitoring of the Main Cables of the Anthony Wayne Suspension Bridge

◆ Weakness

- Only “hears” active breaks. Need current state of cable.

◆ Challenges

- Provide information to assess entire cable volume
- Locate critical areas to inspect.

◆ Mistras is the lead on this project

◆ Also using to monitor concrete crack growth on a noncomposite adjacent box beam bridge

Ultrasonic Examination of Truss Pins



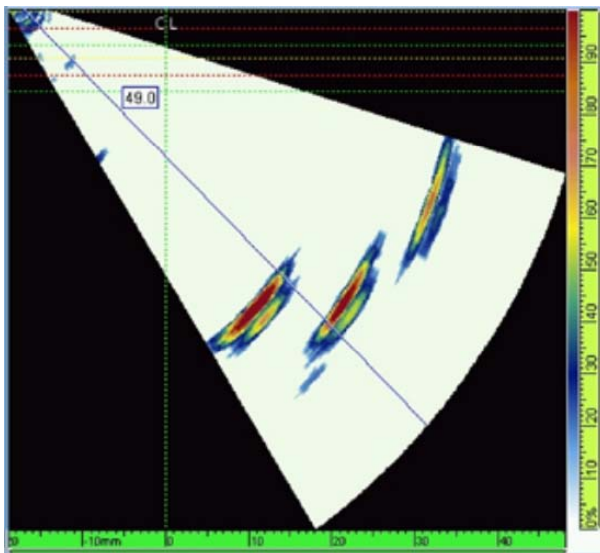
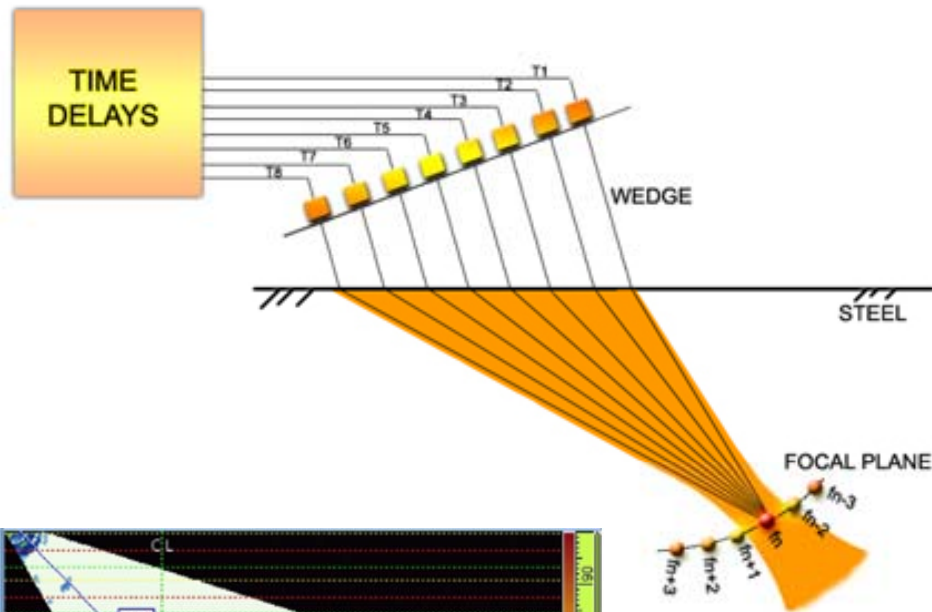
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- ◆ **Uncertainties:**
 - Locate cracks in large truss pins on fracture critical structures
- ◆ **Desire to ascertain:**
 - Size and location of cracks
- ◆ **Quantities to measure:**
 - Ultrasonic reflections from cracks

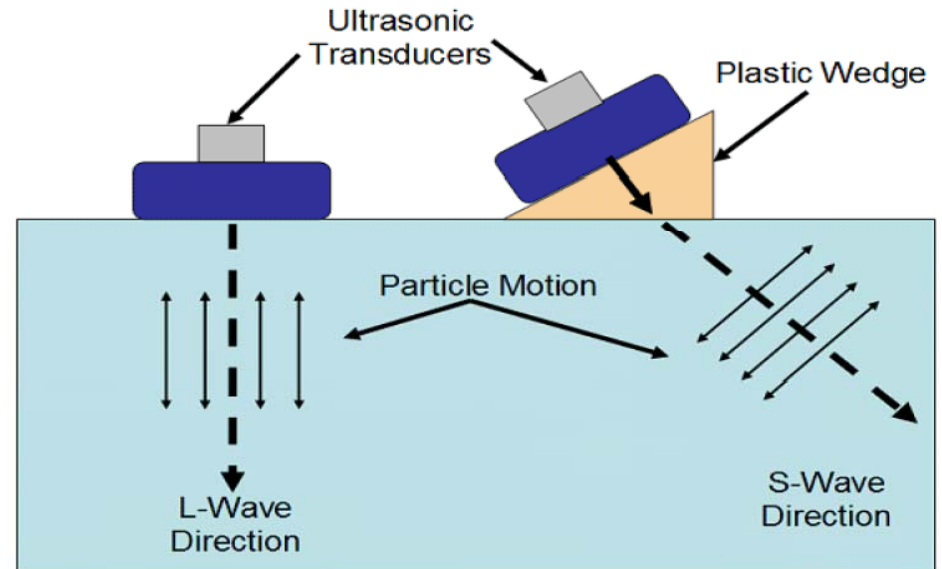


Ultrasonic Examination of Truss Pins

Phased Array Ultrasonic Testing



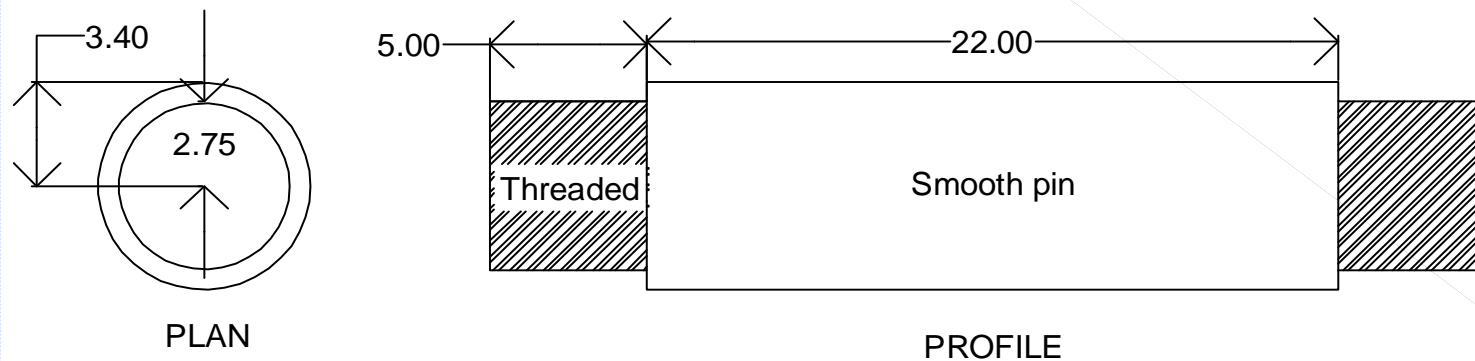
Conventional Ultrasonic Testing



Ultrasonic Examination of Truss Pins

◆ Challenges

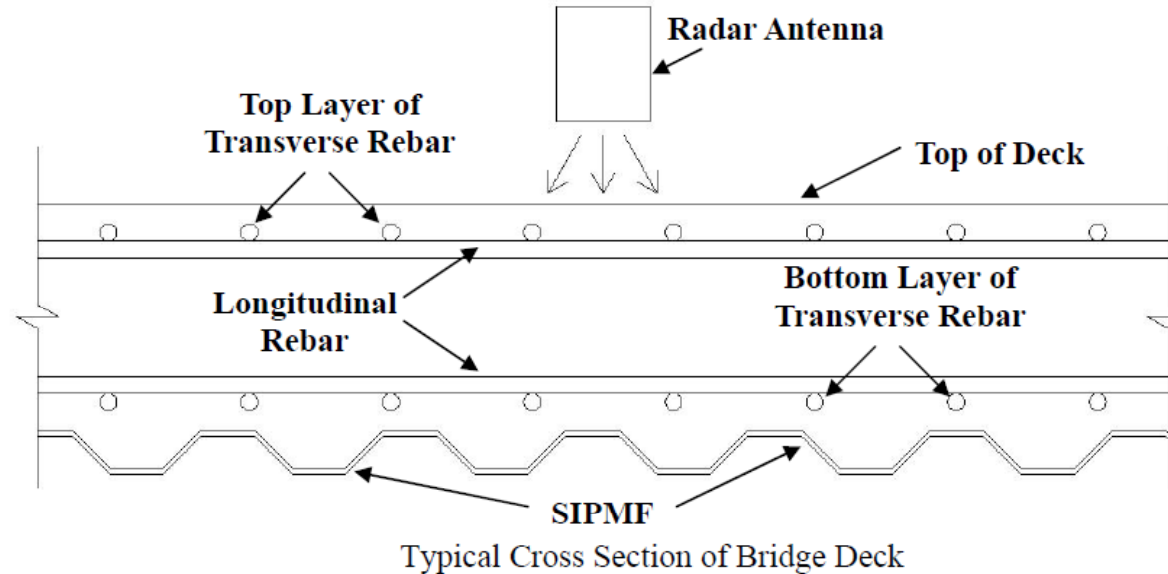
- Assess a the entire volume of the pin from one surface.
- Make information usable for loadrating



Ground Penetrating Radar



- ◆ **Uncertainties:**
 - Condition of stay-in-place metal forms
- ◆ **Desire to ascertain:**
 - Condition of the SIPMF quickly from the top of the deck.
- ◆ **Quantities to measure:**
 - GPR reflection from the SIPMF

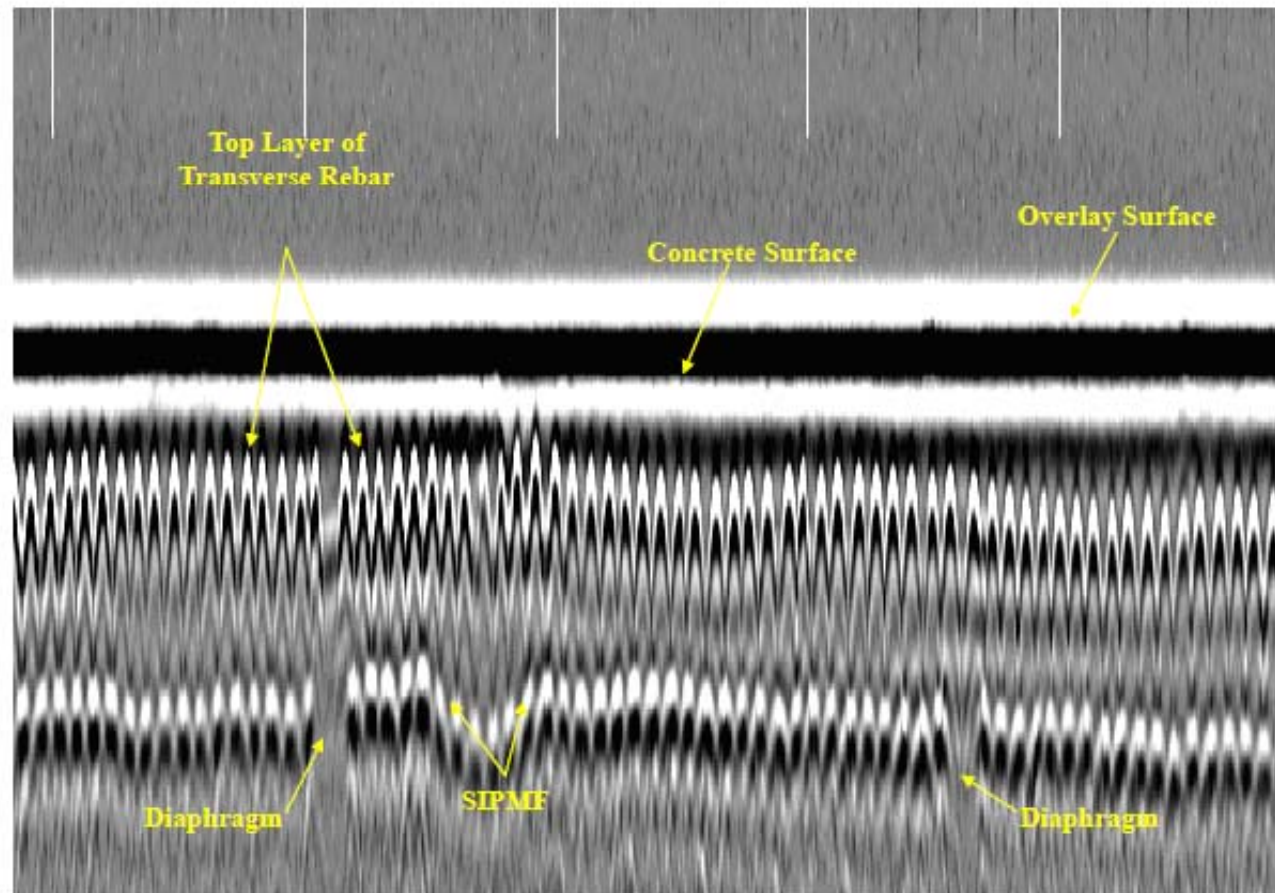


Ground Penetrating Radar



◆ GPR Response

- Affected by moisture
- Early signal contained little data
- SIPMF was shielded by the rebar



Ground Coupled Radar Results



Ground Penetrating Radar

◆ Despite positive initial trial it did not work

- SIPMF too deep
- Not directly measuring what we needed

◆ Challenges

- Can the need for this inspection be obviated?
 - ◆ Quality control
- Is there a technology that works?
 - ◆ Bridge inspectors get a great deal of information from looking at the bottom of a deck

◆ Partner ODOT



Conclusion

◆ We are on our way to an intelligent bridge

- Sensors can complement visual inspection
- Ask the right question. Identify the critical parameters.
- Collect the right data.

◆ Challenges

- It is easy to generate huge streams of data that is only digestible by experts. Make the data accessible in a form an owner can use.
- Put the data into load rating or, in the future, into reliability estimates.
- Be economical. Use sparse arrays.